# EXPERIMENT "PAMIR"-II. "FIANIT" - A GIANT SUPER-FAMILY WITH HALO ( $E_0 \sim 10^{17}$ eV)

Collaboration of experiment "Pamir" *)

1. Introduction. A supefamily with halo of extremely high energy named "Fianit" was recorded in X-ray emulsion chamber (XEC) at the Pamirs (atmospheric depth 600 g/cm$^2$). Here we present detailed description of the superfamily and results of its analysis.

2. Experimental set-up and description of the event. The "Fianit" was recorded in the XEC consisted of two registration blocks separated by the 1 m air gap which permit to evaluate (by a triangulation method) the height of the initial interaction in the atmosphere up to several kilometers. The method and the structure of the XEC were described elsewhere [1,2] . The superfamily was traced in all six layers of the XEC with selection of the cascades in the circle of R = 40 cm. Zenith angle of particle arrival was 18° the height of the initial interaction determined from the relative distances between the single $\gamma$-cascades at various depths in nuclear emulsions is equal to $3{,}5 \pm^{2}_{1.5}$ km. The $\gamma$-quanta of high enough energy used for the estimation of the height were located at distances from 4 to 12 cm from the family center.

In the center of the family there is a large dark diffused spot ("halo"), and on the background of it the separate cascades are visible in the upper layer of the XEC.

The energy determination for individual cascades was performed at the depth of 7.5 c.u., i.e. above the air gap. About 900 cascades are located out of the central circle with R = 2 cm, and they need no corrections taking into account the halo. On the background from halo, in the ring $0.5 < R < 2.0$ cm the energies of nearly 700 cascades were measured after the corrections connected with halo by the technique described in / 3/ . The results of the measurements of cascade energies are given in Table 1. In the region $R > 2$ cm integral spectrum of $\gamma$-quanta has the power index $\beta = 1.8 \pm 0.1$ . As far as the total depth of XEC is equal (taking into account the inclination) to 13.3 c.u. the hadron registration efficiency is $\sim$ 15% only. Selection of hadrons was made at the depth of 13.3 c.u. (the 6th layer) and as a criterion of a hadron-induced cascade served the absence of it at a depth 7.5 c.u. (it corresponds to depth of origin $\Delta t > 6$ c.u.). In the region with $2 < R \leq 40$ cm 46 of such the cascades were observed, 26 of them be-

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ing with energy $E_h^{(\gamma)} \geq 4$ TeV. The power index of this hadron spectrum occured to be $\beta_h = 1.5 \pm 0.2$. Some results of measurements for $\gamma$-quanta and hadrons are given in Table 1.

Table 1

| | Particles with 2cm < R < 40 cm | | All $\gamma$-quanta | |
|---|---|---|---|---|
| | $N_\gamma$ or $N_h$ | $\Sigma E_\gamma$ or $\Sigma E_h^{(\gamma)}$, TeV | $N_\gamma$ | $\Sigma E_\gamma$, TeV |
| $\gamma$-quanta, $E_\gamma \geq 4$ TeV | 250 | $2.7 \cdot 10^3$ | 720 | $1.0 \cdot 10^4$ |
| hadrons, $E_h^{(\gamma)} \geq 4$ TeV | 26 | 192 | - | - |

2. Lateral distributions. The interesting feature of the superfamily "Fianit" consists in some structure of lateral distribution of $\gamma$-quanta. In the target diagram of the family (Fig.1) points the mean centers of the close groups of $\gamma$-quanta (clusters), obtained by the method of "nuclear decascading": to be included in the same cluster each pair of the cascades has to satisfy the condition

$R_{ik} \cdot (E_i^{-1} + E_k^{-1})^{-1} \leq Z_0$, $Z_0 = 30$ TeV.cm ($R_{ik}$ - the mutual distance, $E_i$, $E_k$ - the energies of the cascades).

The number of clusters so obtained with energy $E_{cl} \geq 4$ TeV is equal to $N_{cl} = 55$, while 38 of them are located outside the circle of radius 2 cm. Differential distributions of R and $ER$ for clusters are shown in Fig.1, the average values being $\langle R_{cl} \rangle = 10.5 \pm 1.4$ cm, $\langle E_{cl} \cdot R_{cl} \rangle = 5.8 \pm 0.6$ GeV.km. After the comparison with results of /4/ it can be stated that the high values of $\langle E_{cl} \cdot R_{cl} \rangle$ are connected with large ($\gg 1$ GeV/c) transverse momenta at least for the part of the initial hadrons or jets.

3. Properties of halo. To evaluate the energy of the halo the scanning of the area 4x4 mm$^2$ with a slit size 500x500 $\mu$m$^2$ was performed in the central part of "Fianit" for 5 depths: 3.8, 5.7, 7.5, 11.4 and 13.3 c.u. *) Analysis of the densitograms has shown, that the total number of particles reaches the maximum at 11.4 c.u. although the darkness density is still growing up to the last level, 13.3 c.u. The total numbers of particles at various depths is given in Table 2.

The energy of the halo can be calculated from the total number of particles at maximum of the transition curve and the typical average energy $\sim 10^8$ eV:

$$E_{halo} \cong 1.7 \cdot 10^8 \cdot 10^8 = 1.7 \cdot 10^{16} \text{ eV}$$

*) Scanning was done in P.N.Lebedev Physical Institute (Moscow) and in the Institute of Cosmic Ray Research (Tokyo).

Table 2

| t, c.u. | 3.8 | 5.7 | 7.5 | 11.4 | 13.3 |
|---|---|---|---|---|---|
| $N_{tot} \cdot 10^{-7}$ | 1.2 | 6.3 | 13.4 | 16.6 | 15.1 |

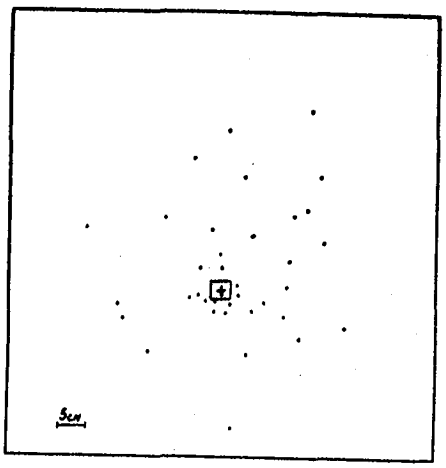


Fig.1. Target diagram of cluster lateral distribution (+ - central region of halo)

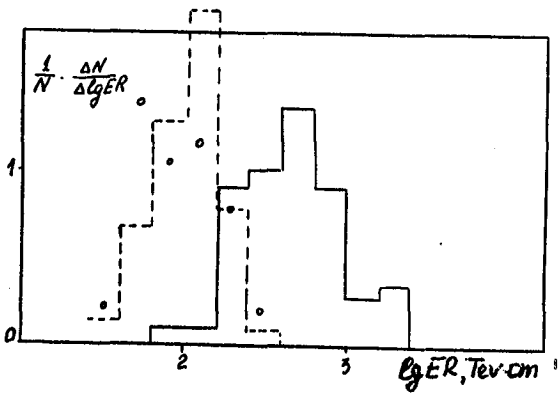


Fig.2. ER distributions of clusters: — -"Fianit", O - big families of Fuji group, --- -calculations by model of high multiplicity

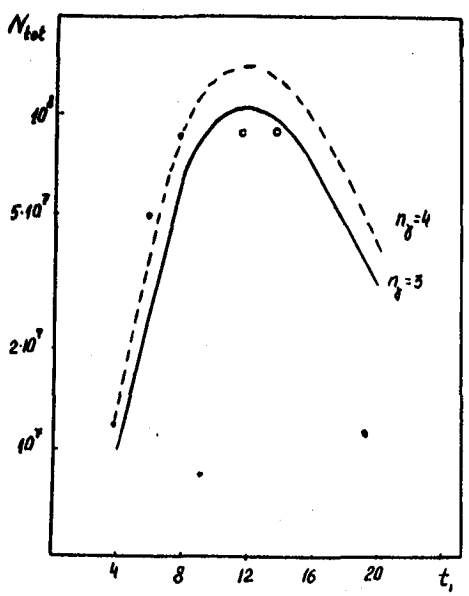


Fig.3. Transition curve of halo particles: • -experiment, — - and --- -calculations for various number of initial $\gamma$-quanta with energy $10^{16}$ eV

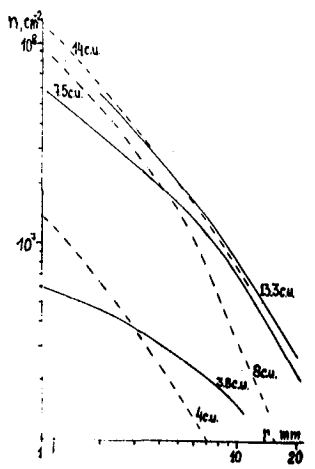


Fig.4. Lateral distributions of halo particles at various depths: — - experiment, --- -calculation /5/

Because of the possible influence of the large air gap this energy estimate is considered as a lower limit.

The comparison of the longitudinal and lateral development of the halo with calculations is given in the Figs.3 and and 4. The last 2 experimental points in Fig.3 are measured under the air gap, so they are underestimated. It can be seen that the longitudinal development can be explained /5/ by the production of 4 initial $\gamma$-quanta with energies of each of them $\sim 10^{16}$ eV at the height $\sim 12$ c.u. above the chamber. However for the lateral structure of halo the calculation differs from reality: it gives too high density in the center and $\sim 2$ times lower at the distance $\sim 1$ cm. This discrepancy cannot be explained by methodical reasons and it is necessary to admit the preduction of the considerable number of $\gamma$-quanta with initial lateral divergence.

4. Conclusions. The total energy of $\gamma$-component of superfamily "Fianit" occured to be $\sim 3.5 \cdot 10^{16}$ eV, the total multiplicity of $\gamma$-quanta $\sim 1500$ so it is now the most energetic event ever recorded by XEC. Its peculiar feature is the large number of clusters (55) anomally wide distributed over $E_{cl}R_{cl}$ values.

References

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